EFFICACY AND RESIDUES OF FOLIAR SPRAYS AGAINST THE LETTUCE APHID, *NASONOVIA RIBISNIGRI* (HOMOPTERA:APHIDIDAE), ON CRISPHEAD LETTUCE

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ABSTRACT

The systemic insecticides disulfoton, oxydemeton-methyl and demeton, were highly effective in controlling the lettuce aphid, *Nasonovia ribisnigri* (Mosley) (Homoptera:Aphididae), when sprayed on crisphead lettuce at the early stage of heading. Total residues of disulfoton, applied at 1.12 kg AI/ha and oxydemeton-methyl at 0.56 kg AI/ha, diminished to less than 0.06 ppm 28 days after application, making these compounds strong candidates to replace the discontinued demeton. The local systemic compounds pirimicarb and methamidophos were intermediate in effectiveness between the systemics listed and contact insecticides such as endosulfan, mevinphos and parathion when applied to lettuce before the heading stage. Seven methods of applying methamidophos at 1.1 kg AI/ha all provided equally significant levels of lettuce aphid control.

INTRODUCTION

The lettuce aphid, *Nasonovia ribisnigri* (Mosley), has been a serious pest of crisphead lettuce in the lower Fraser Valley of B.C. since 1981 (Forbes and Mackenzie 1982). Unlike other lettuce infesting aphids, *N. ribisnigri* is particularly difficult to control at the heading stage with contact-action foliar sprays, since the preferred feeding niche of this pest is sheltered inside the head.

In 1982, several growers reported inadequate aphid control from certain insecticides registered for use against aphids on lettuce. Preliminary efficacy trials substantiated these reports (Mackenzie *et al.* 1982). These trials also showed that weekly applications of methamidophos alternately with pirimicarb, both local systemics, and interrupted at the start of heading by a single application of demeton, a systemic, would give excellent control of the lettuce aphid. This approach (B. C. Ministry of Agriculture and Food 1983) was adopted by growers following registration of pirimicarb in 1983. The demeton application was of key importance in that it provided systemic control of aphids protected within the newly-developing head. The overall effectiveness of this spray schedule, however, was threatened when demeton was withdrawn from the market in 1986.

In preliminary trials, disulfoton, a systemic, was highly efficacious when applied as a foliar spray to pre-heading lettuce. Total residues of disulfoton sprayed at a rate of 1.0 and 2.0 kg AI/ha just before the start of heading fell to less than the present tolerance level of 0.5 ppm in heads sampled 13 days later (Szeto *et al.* 1983). The primary objective of this study was to evaluate disulfoton as a suitable systemic replacement for demeton. Efficacy and residue studies were conducted for disulfoton, as well as for oxydemeton-methyl, a systemic compound structurally similar to demeton. These candidates were assessed for lettuce aphid control alongside a number of insecticides currently registered for use on lettuce.

A secondary objective of this study was to investigate the effect of different spray application techniques on aphid control. Several sprayer settings were compared for control efficacy using methamidophos at two stages of heading.

MATERIALS AND METHODS

Field trials were conducted at the Abbotsford Research Sub-station in 1985 and 1986. In all trials, crisphead lettuce, cv. Ithaca, was precision-seeded in beds, 1.75 m wide by 4 m long, with 4 rows per bed and 35 cm between rows. Adjacent and end-to-end beds were at least 1 m apart. Each bed was assigned a spray treatment, and each treatment was replicated four times, in a randomized complete block design.

Sprays were applied with a hand-pushed, CO_2-pressurized boom sprayer (R and D Sprayers Inc., Opelousas, La.). In the efficacy and residue trials, the spray boom was positioned 50 cm above ground and equipped with three, D4-25 hollow-cone nozzles (Spraying Systems Co., Wheaton, Ill.) spaced 60 cm apart. Treatments were delivered in 600 L of water/ha without spreader-sticker at a pressure of 690 kPa. Control plots were sprayed with water alone.

In all trials, treatments were assessed by examining four or six plants artificially infested with lab-reared *N. ribisnigri* (i.e. at least one infested plant/row in each bed). Plants of uniform size were arbitrarily selected for infestation within the centre 3 m of each bed. Treatments were assessed by cutting off marked plants at ground level and inspecting all leaves closely in the field for aphids.

TABLE 1. Efficacy of sprayed insecticides applied to lettuce on 29 July before the start of heading for control of *N. ribisnigri*, Abbotsford B.C., 1986.

		Number of Lettuce Aphids					
		Alatae		Apterae		Total	
Treatment	Rate (kg AI/ha)	1 Aug.[1]	5 Aug.	1 Aug.	5 Aug.	1 Aug.	5 Aug.
Demeton 240 EC	0.56	8	4	9	23	17 a[2]	27 ab
Disulfoton 720 EC	1.12	3	4	1	7	4 a	11 a
Endosulfan 4 EC	0.84	3	12	28	46	31 a	58 bcd
Methamidophos 480 EC	1.10	2	10	7	33	9 a	43 abcd
Mevinphos 6 EC	0.25	9	15	14	100	23 a	115 e
Parathion 800 EC	0.34	6	12	24	64	30 a	76 cd
Pirimicarb 50 WP	0.25	5	16	5	17	10 a	33 abc
Check	–	21	14	83	68	104 b	82 d

[1] Examination date.

[2] Numbers within a column followed by the same letter are not significantly different according to Duncan's multiple range test, $P < .05$.

Insecticide Efficacy: Pre-Heading Spray Trial

The efficacy of disulfoton was compared with that of demeton and other registered lettuce insecticides in a lettuce planting seeded 19 June, 1986. Just after thinning on 17 July, five lab-reared *N. ribisnigri* apterae were released onto each of four plants selected in each replicate. A subsequent release of 20 more aphids/plant was made on 24 July. Five days after the second release, spray treatments were applied on the early morning of 29 July before the plants had started heading (Table 1). Aphid mortality was assessed on two occasions. Two of the four infested plants/replicate were examined on 1 August ($\bar{X}$ = 10 leaves/plant), and again on 5 August ($\bar{X}$ = 12 leaves/plant) prior to the onset of heading.

Insecticide Efficacy: At-Heading Spray Trial

Two rates of disulfoton and one of oxydemeton-methyl were compared with the registered insecticides demeton and endosulfan in a lettuce planting seeded 2 July, 1985. On 13 and 16 August, just after the start of head formation ($\bar{X}$ = 15 leaves/plant), ten apterae were released onto each of six plants selected in each replicate. After the second release, the aphids were allowed four days to become established on the plants ($\bar{X}$ = 18 leaves/plant) before sprays were applied on the evening of 20 August (Table 2). Aphid mortality was assessed in the field on 22 and 23 August by close inspection of all 24 infested plants/treatment.

Residue Analyses: Disulfoton and Oxydemeton-methyl

The degradation of disulfoton and oxydemeton-methyl residues were monitored in lettuce plantings seeded on 10 and 20 June, and 2 July, 1985 (plantings 1, 2 and 3 respectively). Sprays were applied in the evening of 20 August, 1985 (Table 3) when planting 1 was approximately a week from maturity, planting 2 was in the early heading stage, and planting 3 was at a stage just before heading.

TABLE 2. Efficacy of sprayed insecticides applied to lettuce on 20 August at the start of head development for control of *N. ribisnigri,* Abbotsford B.C., 1985.

Treatment	Rate (kg AI/ha)	Total No. of Lettuce Aphids[1]			Percent Aphid Mortality
		Alive	Dead	Total	
Disulfoton 720 EC	0.56	13 a[2]	43 NS[3]	56 NS	76.8
Disulfoton 720 EC	1.12	4 a	71	75	95.0
Oxydemeton-methyl 240 EC	0.56	8 a	54	62	87.1
Demeton 240 EC	0.56	14 ab	35	48	72.9
Endosulfan 4 EC	0.84	22 ab	47	69	68.1
Check	–	65 b	8	73	11.0

[1] 2 Days after spray application.

[2] Numbers within a column followed by the same letter were not significantly different according to Duncan's multiple range test, P< .05.

[3] NS: none of the numbers within a column were significantly different according to analysis of variance (ANOVA), P< .05.

TABLE 3. Residues of disulfoton and oxydemeton-methyl after foliar spray in three lettuce plantings at different stages of growth, Abbotsford B.C., 1985.

Treatment and Rate (kg AI/ha)	Planting Number	Days From Spray Date to Sample Date	Residues in ppm (Fresh Weight)		
			DSO_2[1]	$DOASO_2$[1]	Total
A. Disulfoton					
1.12	1	6	1.69	0.83	2.52
1.12	2	15	0.13	0.27	0.40
1.12	3	28	TR[2]	0.01	0.01
Check	1	6	0.01	0.03	0.04
Check	2	15	ND[2]	TR	TR
Check	3	28	ND	ND	ND
B. Oxydemeton-methyl			–	$ODMSO_2$[3]	–
0.56	1	6	–	5.84	–
0.56	2	15	–	1.36	–
0.56	3	28	–	0.06	–
Check	1-3	as above	–	ND	–

[1] DSO_2: disulfoton sulfoxide; $DOASO_2$: disultoton oxygen analogue sulfone.

[2] TR: trace amount of residue detected; ND: no residue detected.

[3] $ODMSO_2$: oxydemeton-methyl sulfone. Residues of the parent compound *i.e.* oxydemeton-methyl, were oxidized to the sulfone which then represented the total amount of residue in the crop.

One plant was arbitrarily selected for residue analysis from the centre 3 m of each of the 4 rows/bed (n = 16 plants/treatment). Pooled samples from each replicate were separately analyzed. Planting 1 was sampled 6 days post-spray; planting 2, 15 days post-spray; and planting 3, 28 days post-spray. Only the three outermost wrapper leaves from the selected plants were analyzed. Total residues of disulfoton were determined by a modification of the method reported by Szeto and Brown (1982). In the modified method, all toxic oxidative metabolites were further oxidized with $KMnO_4$ to their sulfones, and recoveries were better than 90%.

Influence of Application Protocol on Insecticide Efficacy

The importance of seven different spray application protocols in controlling *N. ribisnigri* with methamidophos, a registered insecticide, were tested in trials seeded on 12 and 23 June, 1986 (trials 1 and 2 respectively). In the application protocol considered optimum for lettuce aphid control, the sprayer was configured to deliver 600 L of water/ha at a pressure of 690 kPa, using 4 hollow-cone nozzles (orifice size D4-25), each positioned 50 cm above each row. These were used as reference settings (RS) to each of the remaining six protocols tested in which we introduced a single variable from the reference settings. Specifically, the variables were: 1) RS with three nozzles per bed (45 cm apart); 2) RS with nozzles 100 cm above each row; 3) RS spraying at 345 kPa; 4) RS applying 1200 L of water/ha; 5) RS with four flat fan nozzles (size 8003); and 6) RS with spreader-sticker (Super Spread, Reichold-Niagara Chemical Co. Burlington, Ont.). Methamidophos was applied at a rate of 1.1 kg AI/ha in all treatments except the check plots which received water alone applied at the reference settings.

On 25 and 29-30 July, ten lab-reared apterae were released onto each of four arbitrarily selected plants in the centre 3 m of each bed. After the second release, aphids were allowed eight days to become established on the plants before sprays were applied on the early morning of 8 August. Trials 1 and 2 were both in the heading stage (i.e. $\bar{X}$ = 21 and 16 leaves/plant, respectively) when the plants were examined on 11 and 12 August.

RESULTS

Insecticide Efficacy: Pre-Heading Spray Trial

Although a total of 400 aphids were released in each treatment, only 104 were counted in check plots two days after spraying. The drop in aphid numbers could have been a result of a sudden change in environment between the rearing facility and the field, physical dislodging of aphids from plants by water applied to the check plots, natural predation, or a combination of these. Nevertheless, differences between the check plots and insecticide treatments were discernable (Table 1).

All treatments significantly ($P < 0.05$) reduced total aphid numbers compared with check plots when aphid mortality was assessed three days after application. Significant differences between insecticides did not occur at that time, although aphid numbers were higher in plots sprayed with the contact insecticides parathion or endosulfan. Disulfoton was providing significantly ($P < 0.05$) better control than the check, parathion, endosulfan or mevinphos treatments when they were assessed seven days post-spray. This indicates that disulfoton will provide better residual control of *N. ribisnigri* than the registered contact insecticides commonly used on lettuce. Methamidophos, pirimicarb and demeton were intermediate in control between disulfoton and the contact insecticides.

Insecticide Efficacy: At-Heading Spray Trial

Plots treated with disulfoton at 0.56 and 1.12 kg AI/ha and oxydemeton-methyl at 0.56 kg AI/ha, had significantly ($P < 0.05$) fewer surviving aphids than in the check plots (Table 2). Although there were no significant differences between insecticide treatments in numbers of surviving aphids, disulfoton and oxydemeton-methyl at the higher rates provided the highest percent mortality.

Residue Analyses

In a previous trial, head wrapper leaves and 2.5 cm thick vertical slices from the middle of lettuce heads were analyzed for disulfoton residues (Szeto *et al.* 1985a). Residue levels were lower in the head slice samples two days after treatment than in head wrapper leaves 14 days after treatment. The wrapper leaves likely contained higher residues since they were directly sprayed with disulfoton. Therefore, sampling of only head wrapper leaves in the present study provides an overestimation of residues in the total head, and thus is a more conservative approach to determining potential residue hazard in lettuce.

The degradation of residues after application of disulfoton and oxydemeton-methyl are shown in Table 3. Total residues detected in lettuce sprayed with disulfoton at 1.12 kg AI/ha were below 0.5 ppm 15 days post-spray and 0.01 ppm 28 days post-spray. Trace amounts of disulfoton residues found in check plots six days post spray are likely due to low level spray drift. Total oxydemeton-methyl residues were only 0.06 ppm 28 days post-spray.

Influence of Application Protocol on Insecticide Efficacy

The degree of aphid control achieved with methamidophos applied using seven application protocols did not significantly differ between protocols (Table 4) in either of the two plantings treated at heading. Significant ($P < 0.05$) differences, however, did occur between the seven protocols and the check plots. When counts of aphids from the two plantings were totalled, the highest numbers were found in plots sprayed with either four fan nozzles or three hollow cone nozzles. Nozzle style and number/bed, therefore, may be more important in achieving acceptable control than the other sprayer configurations tested. The fewest aphids were found in plots sprayed either at the reference settings or in plots which received twice the volume of water in the spray mix than the reference volume. These data also show a difference in aphid control between treatments applied at different stages of head development. In planting 1 (late heading), a total of 60 aphids were found in treated plots compared with only 29 in planting 2 (early heading).

TABLE 4. Comparison of several sprayer configurations for control of *N. ribisnigri* with methamidophos, Abbotsford B.C., 1986.

	Number of Lettuce Aphids						
	Alatae		Apterae		Total		Total
Treatment	1[1]	2	1	2	1	2	of 1 and 2
Reference Settings[2]	2	0	2	2	4 a[3]	2 a	6
3 Nozzles	8	6	5	2	13 a	8 a	21
High Boom	6	0	5	3	11 a	3 a	14
Low Pressure	2	2	2	2	4 a	4 a	8
High Volume	2	1	3	0	5 a	1 a	6
Fan Nozzles	8	1	4	9	12 a	10 a	22
Sticker Added	2	1	9	0	11 a	1 a	12
Check	3	9	99	141	102 b	150 b	252

[1] Planting number. Planting No. 1 was seeded on 12 June, Planting No. 2 on 23 June, 1986.

[2] See text for an elaboration on the sprayer settings.

[3] Numbers within a column followed by the same letter were not significantly different according to Duncan's multiple range test, $P < .05$.

DISCUSSION

Since a serious outbreak of lettuce aphids in 1982, the Lower Fraser Valley market has imposed a zero threshold for living or dead aphids on harvested head lettuce. Successful control of the lettuce aphid is dependent on routinely and accurately timing specific insecticide sprays with specific stages of crop growth (Mackenzie 1986). Prior to heading, when plants are small and aphids more exposed to insecticide sprays, local systemics such as methamidophos and pirimicarb can achieve almost complete aphid control (Mackenzie 1986). As shown in this study, the local systemics mentioned provided better control than did a number of commonly used contact-action insecticides (Table 1). It is reasonable to assume that local systemics applied routinely and at optimal sprayer settings to lettuce in the pre-heading stage will provide the complete aphid control necessary up to the heading stage.

If aphids are present when the heads begin to form, they are protected within the enclosed leaves from foliar sprays and cannot be completely controlled thereafter. Incomplete aphid control at the heading stage has been observed when growers used non-prescribed insecticides, applied the insecticides incorrectly, or omitted key spray applications. The prescribed use of demeton at the early stage of heading (B. C. Ministry of Agriculture and Food 1983) was to provide systemic control of any aphids not controlled during the pre-heading stage of plant growth. The demeton application, followed by additional routine applications of methamidophos and pirimicarb has proven to be highly efficacious in keeping lettuce heads free from aphids until harvest. Since the manufacture of demeton was discontinued in 1986, the continuing success of the spray program now depends on replacing demeton with an equally efficacious systemic insecticide. The present study shows that disulfoton (Tables 1 and 2) and oxydemeton-methyl (Table 2) are equal to, or better than demeton in controlling lettuce aphids at the early stages of heading. In addition, data presented here, and other data (Szeto *et al.* 1985a and 1985b) indicate that residues of disulfoton fall below the maximum residue limit of 0.5 ppm in lettuce within 28 days of foliar application, and that total residues of oxydemeton-methyl fall to 0.13 ppm. Since heading usually begins about 35 days before harvest, a single application of either disulfoton or oxydemeton-methyl in place of demeton would allow sufficient time for total residues of either insecticide to decline well below allowable limits in harvested heads.

It appears from the spray application protocol study that differences in sprayer configuration may give rise to some variation in efficacy. Although differences in control levels between protocols were small (Table 4) even minor differences are important when virtually complete aphid control is needed. Therefore, in addition to the correct selection and timing of insecticide sprays, attention should be paid to selecting sprayer configurations that will provide the best control.

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